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Spondylolysis in Prehistoric Human Remains From Guam and Its Possible Etiology

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ABSTRACT This study reports the findings of complete bilateral separation of the neural arch (spondylolysis) in 176 inhumations from the Hyatt Site, Tumon Bay, which is located on the west side of the island of Guam. Skeletons were excavated and analyzed by the Paul H. Rosendahl Inc. (PHRI) team in 1989–1990. The inhumations were associated with the pre-European *Latte* Period (circa 1,200–1,521 A.D.). This period was characterized by the use of large stone pillars, called *latte* sets, for the construction of houses. Of the 176 individuals, only 38 adult skeletons had complete spines, and 21% (8/38) of these had evidence of spondylolysis in their lumbar vertebrae, particularly in L-5. The age of the eight individuals range from 30 to 50 years. No children were found with spondylolysis. Of the males 29.4% (5/17) had spondylolysis, as did 14.3% (3/21) of the females. However, the difference between the sexes was not statistically significant. Though the sample is small, it is suggested that the high incidence of lumbar spondylolysis found in these ancient Chamorros was related to lower back traumatic events. The transport of *latte* stones, involving hyperextension and torque of the lower back, while dragging the stones, probably contributed to the development of microfractures in the spine and subsequent spondylolysis. If this hypothesis is correct, then both males and females appear to have been participants in an organized community labor force. It is predicted that similar frequencies of spondylolysis will be found at other *Latte* sites. Am J Phys Anthropol 104:393–397, 1997.

Spondylolysis, or separation of the neural arch, complete or incomplete, has been considered under five different etiologies: 1) a congenital anomaly (Brothwell, 1972; Turkel, 1989; Ubelaker, 1989); 2) a genetic anomaly (Shahriaree et al. 1979); 3) a pathological condition, the byproduct of diseases such as tuberculosis or the consequence of abnormal skeletal development (see Merbs, 1996); 4) a result of severe spinal trauma; and 5) a stress fracture (Merbs, 1989a,b; Merbs, 1996; and Stewart, 1953 among others). Ortner and Putschar (1985) cite the possibility that spondylolysis is a genetic anomaly, but give much more approval to the stress theory. Based on an extensive literature review, Merbs (1996) stated that the last type, the stress fracture, is the most common etiology which he called "typical spondylolysis," while the other four types, he added, are extremely rare. Merbs (1989b) also argued that the lumbar spondylolysis is a unique human condition related to erect posture and the presence of the lumbar curve. He debated that the stresses of daily life subsequently lead to fracture of the vertebral arch. In his words, "the evidence that the

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typical spondylolytic lesion here is a stress fracture is now overwhelming" (Merbs, 1996). This etiological debate is important because the cause and its significance will affect our interpretations of prehistoric populations.

The anatomy of spondylolysis

Spondylolysis which literally means separation of elements of a vertebral body, typically affects the fourth and fifth lumbar vertebrae. The spondylolysis fracture may occur in various parts of the neural arch: pedicles, laminae, and pars interarticularis, the last one being the most common (Merbs, 1989a,b). It can be unilateral or bilateral, partial or complete. If a complete, bilateral fracture occurs at the pars interarticularis, then the vertebra becomes separated into two pieces: the body and superior facets, and the remainder of the neural arch. This anatomical separation may increase the chances of spondylolisthesis, or anterior slippage of the vertebra, because the stability of the vertebral body is lost. Anterior slippage is often prevented by connective tissue such as the anterior and posterior longitudinal ligaments of the spine. According to Merbs (1996) spondylolisthesis can be congenital, stress induced, degenerative, and pathological. Spondylolysis, however, is typical of youth while degenerative spondylolisthesis is a condition seen in older individuals.

Stewart (1953) suggested that the etiology of spondylolysis was traumatic, a product of hyperflexion of the spine while the knees were extended. However, it is now apparent that hyperextension not hyperflexion of the back will likely cause spondylolysis of the vertebra because during hyperflexion the prongs of the vertebra do not impact adjacent vertebra to the same extent as when hyperextension takes place. In the latter, the joints of adjacent vertebra become temporarily tightly locked together causing bone stress.

The stress fracture in pars interarticularis is the most common type of spondylolysis, and it is probably due to a weaker evolutionary "structural design" here than in the pedicles or laminae. From a biomechanical point of view, the inferior processes of a vertebra and their related facets act as a hammer impacting the pars interarticularis region of the contiguous inferior vertebra, which acts as an anvil. With a recurrent hammering force or an acute trauma that exceeds the force sustainable in this interarticular area, stress fracture occurs. For lumbar spondylolysis to take place it looks as if two conditions are necessary, namely, the lower back needs to be either in its normal anatomical position or suddenly hyperextended, increasing the lumbar lordosis, and second the impact or compressive vectors of force, with or without torque, must be great enough for the pars interarticularis (or other area) to give out and fracture (Farfan, 1976; Green et al., 1994).

Merbs (1996) argued that spondylolysis could be the cost of bipedal locomotion. Bipedality would certainly predispose to spondylolysis, but rather than bipedality in and of itself it appears habitual activity is a more likely cause of spondylolysis. In such chronic, severe stress situations, stress induces an imbalance in remodelling, whereby osteoblasts cannot repair stress-induced damage at the stress site as rapidly as osteoclasts are able to destroy bone tissue. The result is weakened bone tissue which is at greater risk for fracture (Ortner and Putschar, 1985).

As Merbs (1989a,b) already pointed out lumbar spondylolysis is more frequently observed in workers carrying out intense physical activities, such as those lifting heavy objects and in athletes such as gymnasts, pole vaulters, football players and divers. Then, hypothetically, people with greater lordosis curves would have a higher risk of developing spondylolysis if they engaged in stressful activities that need hyperextension of the lower back. On the other hand, an increase in normal vertebral kyphosis and/or constant hyperflexion of the spine could result in vertebral compression or anterior vertebral wedging, rather than spondylolysis. With this activity-induced model it is interesting to take a look at the incidence of spondylolysis in the Chamorros' skeletons. The ancient Chamorros built large houses which needed lifting, pulling, and moving of heavy stone pillars.

MATERIALS AND METHODS

From the Hyatt Site, Tumon Bay, which is located on the west side of the island of Guam, 176 inhumations were examined by this author in collaboration with my colleagues, A.L. Stodder, D. Trembly, C. Tucker, and G. Shevick at the Paul H. Rosendahl Inc. (PHRI) Cultural Management Center, Guam. The condition of the skeletons varies from well-preserved to extremely fragmented bones. All the spines were analyzed for evidence of partial or complete breakage of the spinal arch, unilateral or bilateral, and spondylolisthesis. The segment affected was recorded, as well as whether the lamina, pedicle, or pars interarticularis was involved.

The skeletons were excavated by PHRI archaeologists during 1989–1990. Most inhumations had the typical orientation of the *Latte* phase, that is head pointing inland and feet towards the ocean. Shell beads, pestles, sling stones, and plain ceramic sherds were the most common cultural remains associated with the burials. The above archaeological context, as well as, eight radiocarbon dates (Trembly, 1996) place these inhumations with the pre-European *Latte* Period (circa 1,200–1,521 A.D.). Architecturally, this period was characterized by the use of large stone pillars, called *latte* sets, which served as supports for the construction of wooden houses. The *latte* pillars were stone capped and placed in two parallel rows ranging from six to fourteen stones (see Morgan, 1988). Some *latte* sets averaged up to six meters in height, but in Guam most averaged two meters. Morgan (1988) estimated that the largest *latte* columns found on the island of Tinian (House of Taga) weighted fourteen tons each. In Guam each settlement had six to twenty *latte* houses (Morgan, 1988). *Latte* sets are found most frequently in costal zones and the deceased were normally buried under the house.

RESULTS

Of the 176 Hyatt individuals, only 38 had complete spines, and 21% (8/38) of these had complete and bilateral separation of the neural arch (spondylolysis) at the pars interarticularis, particularly in L-5. No partial breakage of the pars interarticularis, pedicles, or lamina were observed. Thus, in the following discussion the term spondylolysis will be used to indicate complete and bilateral separation of the neural arch, unless noted otherwise. Seven cases had lumbar spondylolysis involving one vertebra, and in only one case, a male judged to be over 50 years of age, two vertebras (L4 and L5) were involved. The age of the eight individuals with spondylolysis ranged from 30 to 50 years. No children were found with spondylolysis. Of the males 29.4% (5/17) had spondylolysis, as did 14.3% (3/21) of the females. However, the difference between the sexes was not statistically significant (chi-square = 1.3; df = 1; $P > 0.05$). In all cases spondylolysis was complete and bilateral at the pars interarticularis.

DISCUSSION

Population frequencies of spondylolysis

It is true that the frequency of spondylolysis varies from population to population, but is this due to inheritance (a genetic predisposition) or biomechanical stress? Since most populations have some affected individuals, and as Merbs (1989a,b) has suggested, there are specific activities, such as pole vaulting, that increase the chances of hyperextension of the back; this author is inclined to side with Merbs' stress hypothesis. That is, lumbar spondylolysis appears to be an environmental/cultural condition due to biomechanical stress rather than congenital or genetic anomalies.

What is clear, is the wide range of prevalence of spondylolysis in different populations, with males usually having higher percentages than females in a ratio of about 2:1. In the case of the Chamorros, the equal prevalence of spondylolysis between males and females could be the product of a small sample size. Given the immense size and weight of the stones, a more likely explanation is that both sexes participated in the dragging and lifting of the *latte* stones. Future work on musculoskeletal stress markers need to be undertaken to sustain this view.

Apparently some populations are more affected than others. According to Merbs (1989a), American Blacks have the lowest

mean frequency, 2.0%; while American Whites (4.4%), Japanese (7–11%), and Amerindians (19–29%) cluster in between; and Eskimos and Aleuts have the highest percentages of spondylolysis, 15–54% and 23–25%, respectively. Sexual dichotomies and population variations in prehistoric and protohistoric populations are more likely linked to daily activities, rather than genetic differences per se.

Spondylolysis and/or spondylolisthesis may cause lower back pain. This author has noted that the area of breakage, especially at the pars interarticularis does not always reabsorb into smooth margins. Sometimes sharp osteophytes develop in the area of the fracture which clearly leads to soft tissue impingement in some cases. Most cases of spondylolysis appear to be asymptomatic, but spondylolisthesis is a more severe condition (Merbs, 1996). However, spondylolisthesis was not noted in the Chamorro sample.

In a recent on-going analysis, Arriaza (1995) also found a high frequency of spondylolysis, in a sample from late Chinchorro fishing populations from Arica, Chile (circa 2,000 B.C.). About 18% (5/28) of the Chinchorro males had complete bilateral separation of the neural arch. The condition was absent in the twenty-three Chinchorro females studied. This type of stress-related fracture indicates the Chinchorro males were doing physically demanding tasks involving hyperextension of the back. Therefore strict division of labor existed. This male predominance of the condition is consistent with previous bioarchaeological studies. The rocky coastal area where the Chinchorro people lived and their maritime subsistence, hunting sea mammals and collecting shellfish from slippery rocks could certainly have caused their spinal trauma.

SPONDYLOLYSIS IN CHAMORROS

Though the Chamorro skeletal sample is small, it is hypothesized that the 20% incidence of spondylolysis noted in pre-European contact Chamorros from the Hyatt site was a consequence of their stressful daily activities. These activities likely included harpoon fishing and the occasional pulling, lifting and transporting heavy objects such as the enormous *latte* stones used as pillars for their houses. The *latte* stones were not moved every day, but this does not invalidate the hypothesis, because the acquisition of spondylolysis can be the consequence of one working incident. In addition, the sporadic dragging and lifting of *latte* stones certainly required plenty of muscle constriction, hyperextension and torque of the lower back predisposing the Chamorros to acute vertebral trauma such as spondylolysis. Moving the *latte* stones was literally a back breaking experience. Unlike the Chinchorro evidence for division of labor on the other side of the Pacific, the similar frequency observed in Chamorro females and males, could indicate that dragging heavy stones was a cooperative effort. Certainly, cutting and moving the heavy *latte* stones required a well organized large community labor force, though it is not clear how the Chamorros moved the *Latte* from the quarries or how they erected the pillars. Morgan (1988) suggested "that levers, successive layers of earth fill, quite likely ropes, and log rollers may have been used in erecting the foundation stones of the House of Taga." Similar techniques may have been used on Guam. If the biomechanical model for acquiring a lumbar spondylolysis is correct, it is therefore predicted that comparable frequencies of spondylolysis will be found for other contemporaneous *Latte* Phase skeletons from the Mariana Islands because these populations performed similar tasks.

In summary the ancient inhabitants of Guam were commonly affected by complete and bilateral spondylolysis at the pars interarticularis. At the theoretical level it appears that different activities among various populations can be correlated to their different percentages of spondylolysis rather than differences in genetic affiliation. Future studies need to acknowledge the possibility of lumbar spondylolysis as a stress activity induced vertebral fracture, either acute or chronic, rather than a congenital pathology. Thus, the frequencies of spondylolysis will vary according to environment and cultural activities. The possible occupational activities that induced this stress fracture in a particular population must then be deduced from the regional archaeological evidence.

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